PROGRESS REPORT

Nineteenth Quarter

December 1, 1965 - March 1, 1966

LOW-POWER, LOW-SPEED DATA STORAGE AND PROCESSING TECHNIQUES

National Aeronautics and

Space Administration

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DEPARTMENT OF ENGINEERING

AND APPLIED SCIENCE

YALE UNIVERSITY

PREFACE

The following is the tenth Progress Report on the National Aeronautics and Space Administration Research Grant NsG-138-61, entitled "Low-Power, Low-Speed Data Storage and Processing Techniques." It covers the Nineteenth Quarter beginning December 1, 1965.

The work will be covered by descriptive reports outlining the progress and direction of the research and will state in simple terms the important conclusions. Detailed technical studies will be published in a series of Technical Notes as soon as they are completed.

Richard Clark Barker
Director

STATEMENT OF OBJECTIVES

The purpose of this research is to improve the technical capability to perform memory functions in spacecraft. The study includes special purpose, preprogrammed memories, memories that perform data-analysis functions, and general-purpose memories, including content-addressed and command-addressed memories.

At the present time, the demands of spacecraft development schedules require early commitment to developed memories and well-established circuit techniques. The research covered by this grant is designed to bring together the newest techniques and materials in a manner relevant to spacecraft application so that improvements in memory designs can be realized from basic technical advances as rapidly as possible. The results should be applicable to a wide variety of spacecraft missions.

An important part of the study is to assemble information on a variety of memory techniques so that it will be available to NASA instrumentation groups and associated groups planning space experiments.

SUMMARY OF WORK FOR THE NINETEENTH QUARTER

New Devices

A comprehensive review of the objectives and scope of the work on tunnel devices was given in the most recent progress report. This report will be confined to progress made in the most recent quarter.

Our efforts have been almost exclusively confined to experimental work during this period. The problem is to get good continuous oxides of uniform thickness in the range of 20 - 100 Angstroms, and to get contacts on them without punching them through. We were at first getting good reproducible junctions with a narrow strip of nickel oxidized, and with a thin strip of copper over the top. Comparison of current densities with theory showed that it was very possible that the center of the nickel strip was very heavily oxidized and that we were tunneling just through the edges. We decided, therefore, that we would have to add an insulator to mask off all but a small area in the middle that could be measured. It should be noted that all of the tunneling work reported in the literature follows the practice of measuring the current density and calculating "effective" area, which usually turns out to be in the order of a few percent of the actual geographical junction area.

The masking procedure was to put a flat narrow lengthwise wire over the nickel strip and evaporate silicon monoxide over it. The result is a glass-covered nickel strip with a narrow bare strip down the middle. We then oxidize through the hole and evaporate copper contacts in the form of right angle strips, making nine junctions at a time. We have experimented both with oxidizing through the hole and with oxidizing before applying the SiO. Oxidizing first has the disadvantage that it is almost impossible to put the wire mask over the oxide without scratching it. It is found that SiO is unstable if it is evaporated at too low a substrate temperature. Thus, we find it necessary to evaporate with a substrate of about 300 degrees C. At this temperature, the SiO is quite mobile on the nickel surface, and it runs under the mask putting an insulating layer on the junction as thick or thicker than the desired oxide. Thus we have been forced to seek a better way of protecting the nickel surface while putting on the SiO.

In an attempt to solve this problem, we have worked out a technique of evaporating a sodium chloride masking strip which performs the function intended by the wire. Over the sodium chloride, which is adhered to the nickel, we then evaporate the SiO, wash off the NaCl in an ultrasonic cleaner, and oxidize the nickel through the remaining hole. The problem of getting a uniform oxide within the little slot remains. The evidence for the problem is that some of the junctions measure short circuited. We see no evidence of gross defects in the center of the junction. By applying current to the junction and observing it right after removal from the liquid nitrogen, we see ice melting at spots along the edge of the junction. This tends to localize the source of heat, but no more direct measurement than that is possible at this time.

With the exception of certain experimental accidents, we are now getting good junctions by the above procedure. However, the current densities still indicate that the percentage of the active area is small. The variables under study are the oxidization rate under variable biasing conditions, the surface roughness of the film, which depends on evaporation temperature, and which also affects the oxidization process, and the surface of the glass substrates. Under the surface contrast interferrometer, there are often found long straight scratch-like ridges or valleys. These are probably in the 5 to 10 Angstrom range in height. It is interesting that after a 15,000 Angstrom film has been deposited on top of these ridges, they remain almost perfectly replicated on the film surface. It is possible that ridges like this produce a shadowing effect during the oxidation process and cause short circuits through the thinnest part of the oxide.

Our newest evaporation system has been in full operation during this period, and is being used to make side studies of the surfaces of nickel films as a function of temperature during evaporation, and related studies. There has been a sudden encouraging increase in the yield of nickel platelets in our vapor transport process. This appears to be due to our success in bringing the gas flow under control and partly to the purity of the nickel bromide. There were a few runs in which we got large numbers of platelets with 111 faces, which are exceedingly rare. Experiments are in progress to try to oxidize and put contacts on these platelets, but they are very hard to handle and the success has eluded us so far.

Spacecraft Memory System

Activity on this project, which was suspended when R. M. Lockerd left Yale, has been reactivated. Lockerd is again proceeding with the writing up of this research, and completion of the experimental memory system is anticipated during the next quarter.

The theoretical work being written up is 80 to 90 per cent complete and should be finished in the early summer. It concerns a study of the behavior of buffer memory loaded from a set of experiments which are source encoded with a redundancy removal code. Bit-plane encoding is an example of this technique. The study also includes some further investigations of bit-plane encoding and some techniques for controlling the rate of accumulation of data so as to match, on the average, the accumulation rate and the transmission rate.

Mr. H. K. Kim, who is in his third year of graduate study, is now working full-time on the experimental memory and is planning to continue with buffer memory design problems which include the control of the telemetry sequencing system. With some specific implementation requirements at hand, we are trying to evolve a general approach to onboard data processing. This might be thought of as the opposite to approaching the problem with the tools of general switching theory and an intellectual commitment to the general purpose computer. It is our belief that the useable result will consist of a limited number of programmable multipurpose elements or subsystems, which is essentially a compromise solution.

Ferrites

Theoretical studies of microscopic magnetization processes have been made in recent months in which we have reviewed in detail the work published in the literature and worked out all the details. The objective is to see where the analysis is limited by the fact that we have polycrystalline materials instead of ellipsoids and to see if there is something that can be done about it. Some progress has been made in estimating internal field gradients generated by the divergence of M at the grain boundaries. We are now investigating the likelihood of coupling a significant amount of energy into spin waves with fast rise pulses, and evaluating the effects of anistropy on the parameters.

On the experimental side, there are still some problems that are not quite solved. We have had some difficulty with the zero balance of the digital readout scope and with the memory tracking speed. The memory was designed with storage capacitors that were too large and decayed much too slowly on decreasing signals, which made the automatic plotting of switching curves impractical. One of the problems with this instrument is that it will not measure voltage unless it operates on its own internal sweep. Thus we have had to do gating and sweep triggering from an external 531 oscilloscope, in which the voltage levels available are not compatible with the 567. Some of these circuits have been redesigned, and some of the 567 problems have been eliminated by circuit modifications. The memory has been speeded up by capacitor changes. The Type O integrator has, in effect, been inserted into the 567 system at the optimum point by bringing out some of the internal signal points, adding a mode switch on the front panel, and building a new amplifier into the 3S76 plug-in unit. This work should be at last complete within the next month.

Other Instrumentation

Final calibration, standardization of components for interchangeable boards, and operation manuals have been completed for our major electronics instrumentation projects. These consist of 10 power pulse generators, two pulse pattern generators, and two integrators. These instruments are highly successful and represent a capital investment that we could not have made for commercial equipment.

Plans

During the next quarter, the projects reviewed above will be continued as indicated.